4th Quarter 2006 Progress Report

Reporting Period: October 1, 2006 – December 31, 2006

Axial Capacity of Piles in Intermediate Geomaterials

MDT Project No. 8117-32, MSU Project No. 4W0961

Submitted by:

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Task 1: Project Management/Administration

Project work was initiated in May 2006 with an internal kick-off meeting at Montana Department of Transportation (MDT) in Helena, MT. This meeting clarified the tasks and goals of the project as well as the project data required to complete the analysis. The first quarterly report was a conference call completed on October 5, 2006.

Throughout the project, Dr. Mokwa has overseen the various tasks associated with the project. Weekly meetings were held between Dr. Mokwa and the graduate research assistant (Heather Brooks).

Task 2: Literature Review

The background literature review is essentially complete; however, if a topic requires greater understanding or additional information, the literature review will be expanded as necessary. Review topics included: engineering characteristics of Intermediate Geomaterials (IGMs), deep foundation design in IGMs, wave equation analysis, GRLWEAP background information, and DRIVEN background methods.

Based on our review of approximately 40 technical publications that address IGMs, it appears the majority of research on the material properties of IGMs has been directed primarily towards mudstones (claystone and siltstone) and sandstones. There is not a consensus in the literature regarding a precise definition of IGMs. However, it is generally agreed upon that IGMs can be defined or characterized using Mohr-Coulomb strength parameters. Based on our literature review, the following strength values appear reasonable for characterizing IGMs, for the purpose of this study:

- at least 500 kPa (10,000 psf) unconfined compressive strength, or
- a minimum standard penetration test blow count of 50 blows per 0.3 m (1 ft).

More details and specific references regarding this assessment will be provided in the final report. For the 12 projects provided for analysis by MDT; sandstone, siltstone and claystone are the most common IGMs. The one exception is the dense silty gravel IGM that is identified within the lithology of the Swan River Bridge Project (CN No. 4228).

We have determined that very little published information is available in the literature pertaining to piles driven into layers or deposits characterized as IGMs. By far, the majority of published information on deep foundations bearing in IGMs is related to research and testing conducted on drilled shafts.

Background papers published by the authors of computer programs DRIVEN and GRLWEAP describe the results of sparse research on the use of these computer programs for piles in IGM's. The research is quite limited and very little guidance or recommendations are provided that apply to the issues being addressed in this study (i.e., the modification of soil parameter inputs to match field conditions). Hand calculations using the Nordlund method for pile capacity in cohesionless soils have been completed to verify DRIVEN calculations and to enhance the student investigator's understanding of the program calculations and assumptions.

Results from the technical literature review clearly indicate the potential significance and importance of this on-going study to enhance the current state of knowledge on this subject and to provide practical guidance for analysis and design.

Task 3: Data Collection

Project data was collected and compiled for analysis with the help of personnel from the MDT geotechnical engineering group. Information and data were obtained from various sources, including: engineer analysis/design calculations, pile driving hammer approval memos, design reports, contract plans and, if available, pile driving analyzer (PDA) reports.

Table 1 includes a summary of the data that the MSU design team has compiled to date, and the intermediate geomaterials (IGM) that were encountered on each project. The shaded cells indicate data that are still required in order to perform analyses on the selected priority projects (i.e., those containing PDA reports).

As of December 2006, data input is about 95% complete for priority projects, and the development of soil profiles is about 50% complete for priority projects.

Action Items for Next Quarter:

* Continue organizing and processing data for analysis.

Task 4: Analysis and Synthesis of Results

On-going research involves analyses using the computer programs GRLWEAP and DRIVEN, with a focus on matching the design inputs in DRIVEN to the outputs of GRLWEAP on the projects shown in Table 1. Table 2 includes a summary of the completed analyses. Some of the required data is still needed in order to continue (or start) analyses on certain projects. A summarized list of data that we need to continue evaluation of specific projects is provided in Table 2. We continue to appreciate the ongoing cooperation and assistance of the MDT Geotechnical group in compiling the needed information. Table 2 will be updated during the course of the study as a means of charting and tracking the progress of analysis. Updated versions of this table will appear in subsequent reports.

Based on analyses conducted to date, we have observed that cohesive IGM's are best modeled using a function of their unconfined compression strength and the strength of cohesionless IGM's should be modeled using a friction angle. In GRLWEAP, a parametric study was conducted to determine the parameter that has the most impact on the final output of the program. The inputs of quake and damping were individually varied for the IGM layer, and the effects of relative changes to these variables were compared. A summary of the results are provided in Table 3. It was found that varying damping had the greatest effect on the final pile-driving blow count calculated by the program.

A trail and error spreadsheet has been developed to track each iteration of analyses within DRIVEN and GRLWEAP. The spreadsheet will significantly aid in the final compilation of data for this study.

Action Items for Next Quarter:

* Continue DRIVEN analysis with a focus on cohesionless IGM's.
* Start GRLWEAP analysis with a focus on damping variation.
* Begin developing written summaries of analyses.

Task 5: Report

Quarterly Progress Reports

Action Items for Next Quarter:

* Establish a day and time for the telephone conference call for Quarter #1, encompassing January through March 2007.

Final Report

Work on the final report has already begun on the background information for the study.

TABLE 1. Summary of Projects and Data Categories

Project	CN #	IGM Type	PDA on Project	Bore Logs	Design Report	Driving Logs	PDA Report	DRIVEN Calcs.	GRLWEAP Calcs.	Plans	Hammer Data
***NW Sidey-N**	**1041**	**Siltstone, Coal**	**N**	**Y**	**Y**	**Y**		**Y**		**Y**	**Y**
Milk River- Zurich	1154	Sandstone, Siltstone	N	Y	Y						
*Volberg N &S	1514	Claystone, Siltstone, Sandstone, Coal	N	Y	Y			Y		Y	
Vic. White Coyote Rd.	1744	Gravel with Silt and Sand	Y	Y	Y		N	Y		Y	
***Nashua- E & W**	**2144**	**Claystone, Shale**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**		**Y**
Colstrip- South	2148	?	N			Y					Y
***Angela- N & S**	**2461**	**Shale**	**N**	**Y**	**Y**	**Y**		**Y**	**Y**		**Y**
***Poplar River- NW**	**2792**	**Claystone**	**N**	**Y**	**Y**	**Y**		**Y**			**Y**
Willow Cr.-NE of Blackfoot	3399	Shale	N	Y				Y		Y	
Cutbank Cr.- NE of Blackfoot	3400	Shale	N	Y	Y						
*N. Fk. Poplar Rv.- 27 km S of Scoby	3417	Claystone, Sandstone	Y	Y		Y	Y	Y	Y		Y
Shokin Cr.- S. of Ft. Benton	3887	Shale, OC Clay	N	Y	Y			Y	Y	Y	Y
Little Missouri River-E of Capitol	3988	Shale, Sandstone	N	Y	Y					Y	
Tongue River-Miles City	3989	Dense Gravel, Siltstone, Sandstone	N	Y				Y	Y		Y
Tongue River-Miles City	4174	Dense Sand, Siltstone, sandstone	N	Y				Y	Y		Y
*Swan River-3km SE of Ferndale	4228	Dense Silty Gravel	Y	Y	Y		N	Y	Y		Y
*Bridger Cr. 3 km NE of Bozeman	4230	Dense Silty Sand	Y	Y		Y	Y	Y	Y		Y
*Structures- S of Pray	4232	Very Dense Gravel	N	Y				Y	Y	Y	Y
USRS Canal-3km NE of Augusta	4235	Claystone, Siltstone, Sandstone	N	Y	Y	Y					Y
***Big Muddy Cr.-SE of Redstone**	**4239**	**Claystone**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**		**Y**
*Keyser Cr.-2km W of Columbus	4244	Shale, Sandstone	Y	Y	Y		Y	Y	Y	Y	Y
Wolf Cr.- 3km E of Vida	4268	Shale, Coal, Siltstone	N	Y	Y			Y		Y	
***Big Hole River-3km SW of Jackson**	**4539**	**Sandy Gravel**	**N**	**Y**	**Y**	**Y**			**Y**	**Y**	**Y**
Milk river- W of Chinook	5559	OC Clay, Sandstone, Siltstone, Shale	N	Y	Y			Y	Y		Y

Notes for table:
1) "*" Indicates 1st priority projects for analysis (see Table 2).
2) Shaded cells indicate data that is needed for analysis of 1st priority projects.
3) Bolded Projects have enough information to complete full analysis.
3) Y = yes, WTI has information; N = no, WTI does not have PDA information

TABLE 2. Summary of Analytical Tasks for 1st Priority Projects

Project	**CN #**	**Data Input**	**Soil Profile Drawing**	**DRIVEN Analysis**	**GRLWEAP Analysis**	**Notes**
NW. Sidney-N.	1041	X				DRIVEN 1.0: apparent error in report calculations (evaluating suitability of project for this study)
Volberg-N & S	1514	X				Driving logs, GRLWEAP analysis, and pile hammer data are needed for analysis.
Nashua-E &W	2144	X	X	X		
Angela- N & S	2461	X				
N. Fk Poplar	3417	X	X	X		Design report is needed to analyze the complete project.
Swan River	4228	X	X			Driving logs and PDA reports are needed when they are completed (project under construction).
Bridger Cr.	4230	X	X			Design report is needed for analysis.
Structures S. of Pray	4232					Design report, driving logs, and PDA reports are needed in order to complete analysis.
Big Muddy Cr.	4239	X	X			
Keyser Cr.	4244	X				Driving logs are needed to complete analysis.
Big Hole River	4539					DRIVEN calculations are needed for analysis.

Notes:
1) "X" indicates completed task.

TABLE 3. Summary of GRLWEAP Parametric Study

Quake		Damping		Blow Count	Parameter Change	Blow Count Change	Ratio of Observed Changes
Shaft	Toe	Shaft	Toe				
(mm)	(mm)	(s/m)	(s/m)	(blow/0.3m)	(%)	(%)	(see Note 2)
2.5	2.5	0.65	0.5	87.4			
3	2.5	0.65	0.5	87.6	20.00%	0.23%	87.40
3.5	2.5	0.65	0.5	87.7	40.00%	0.34%	116.53
4	2.5	0.65	0.5	87.9	60.00%	0.57%	104.88
4.5	2.5	0.65	0.5	88	80.00%	0.69%	116.53
5	2.5	0.65	0.5	88.2	100.00%	0.92%	109.25
2.5	3	0.65	0.5	89	20.00%	1.83%	10.93
2.5	3.5	0.65	0.5	90.8	40.00%	3.89%	10.28
2.5	4	0.65	0.5	92.6	60.00%	5.95%	10.08
2.5	4.5	0.65	0.5	94.5	80.00%	8.12%	9.85
2.5	5	0.65	0.5	96.7	100.00%	10.64%	9.40
2.5	2.5	0.7	0.5	89.1	7.69%	1.95%	3.95
2.5	2.5	0.8	0.5	92.6	23.08%	5.95%	3.88
2.5	2.5	0.9	0.5	96	38.46%	9.84%	3.91
2.5	2.5	1	0.5	99.5	53.85%	13.84%	3.89
2.5	2.5	1.1	0.5	102	69.23%	16.70%	4.14
2.5	2.5	1.2	0.5	105.5	84.62%	20.71%	4.09
2.5	2.5	1.3	0.5	109.1	100.00%	24.83%	4.03
2.5	2.5	0.65	0.6	94.3	20.00%	7.89%	2.53
2.5	2.5	0.65	0.7	100.2	40.00%	14.65%	2.73
2.5	2.5	0.65	0.8	106.7	60.00%	22.08%	2.72
2.5	2.5	0.65	0.9	113.2	80.00%	29.52%	2.71
2.5	2.5	0.65	1	119.5	100.00%	36.73%	2.72

Note:

1) Calculations performed using data from Nashua Creek project, CN 2144, Bent #1.
2) "Ratio of Observed Changes" is calculated as: (% parameter change) divided by (% blow count change).

Summary of Expenditures

Table 4 summarizes the expenditures on this project through December 31, 2006. Total dollar expenditures for the project through December 31, 2006 were $10,460.88, leaving $29,580.12 for the remainder of the project. Travel expenses were slightly higher than originally budgeted as a result of an unplanned but useful field trip by the graduate student researcher (Heather Brooks) to observe pile driving installations on the MDT Swan River Bridge Project in Big Fork, MT, and the MDT Bear Canyon Bridge Project, located near Bozeman. To minimize travel expenses, the graduate assistant stayed at a friend's house in Helena during her data collection trip to MDT headquarters in June. The in-state travel expenses also include travel costs for a day trip from Bozeman to Helena for the project kick-off meeting in May.

TABLE 4. Budget Summary

Budget Category	Budgeted Funds	Spent Quarters 2-3	Spent Quarter 4	Total Spent	Total Remaining
Salaries	$15,039.00	$310.83	$101.05	$411.88	$14,627.12
Benefits	$4,525.00	$96.20	$40.92	$137.12	$4,387.88
In-State Travel	$300.00	$89.00	$311.07	$400.07	($100.07)
Out-of-State Travel	$0.00	$0.00	$0.00	$0.00	$0.00
Expendable Supplies	$50.00	$0.00	$0.40	$0.00	$50.00
Tuition	$0.00	$0.00	$0.00	$0.00	$0.00
Subcontracts	$0.00	$0.00	$0.00	$0.00	$0.00
MDT Direct Costs	$19,914.00	$496.03	$453.04	$949.07	$18,964.93
Overhead	$3,983.00	$99.23	$90.60	$189.83	$3,793.17
MDT Share	$23,897.00	$595.26	$543.64	$1,138.90	$22,758.10
WTI/MSU Share	$16,144.00	$5,356.94	$3,965.04	$9,321.98	$6,822.02
Total	$40,041.00	$5952.20	$4,508.68	$10,460.88	$29,580.12

Project Schedule Summary

An updated summary of the project schedule is shown in Figure 1. The project is essentially on schedule and the budget is on track with anticipated forecasts.

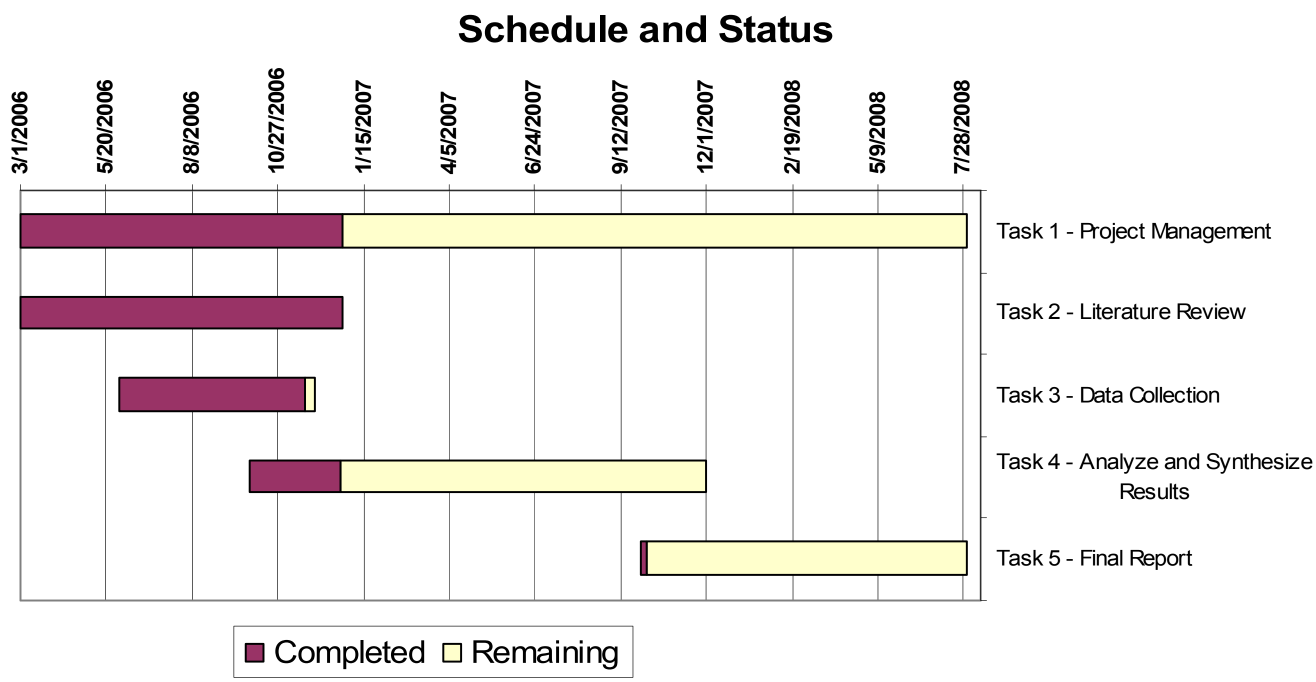

FIGURE 1. Project schedule summary.